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Review

Physical activity and exercise in children with chronic health conditions

William F. Riner [a,*], Sarah Hunt Sellhorst [b]

[a] Health Services, University of South Carolina Lancaster, Lancaster, SC 29720, USA
[b] Gregory Health and Wellness Center, University of South Carolina Lancaster, Lancaster, SC 29720, USA

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Abstract

In the last two or three decades, physical activity (PA) has gained increasing recognition as being essential for maintaining good health and improving quality of life for all ages. Children have traditionally been active in both free play and organized sports. However, there has been a recent decline in the PA levels among children for various reasons. This lifestyle change has resulted in increased obesity accompanied by a rise in diabetes and cardiovascular risk among otherwise healthy children. These lifestyle changes have been shown to be even more a problem when the child is already affected by a chronic disease. Due to medical limitations and contraindications, much care must be taken to make certain that these children are involved in the appropriate volume and intensity of exercise. The type of activity must also be given careful consideration to avoid undue risk for the child who may have problems such as poor balance, limited strength, poor vision, or cognitive disability. Further complications are either caused or exacerbated by lack of sufficient PA. The priority beyond concern for safety should be focused on ensuring the highest quality of life possible. The purpose of this review is to examine how PA can benefit children with selected chronic health conditions.

Keywords: Children; Chronic health condition; Exercise; Physical activity

1. Introduction

The prevalence of chronic disease in children and young adults has doubled between the 1960s and 1980s and has continued to increase into the 21st century.[1–3] Prevalence rates of chronic diseases in children are often hard to ascertain due to the varying conceptual definitions and differing approaches to measurement.[4] The 2007 U.S. National Survey of Children's Health showed that 13.6% of children aged 0-17 surveyed had at least one current chronic condition excluding obesity while 8.7% had two or more chronic conditions.[5] According to the 2009/2010 U.S. National Survey of Children with Special Health Care Needs, 65.6% of respondents indicated that their health conditions affected their daily activities at least some of the time.[6]

Maintaining the health and functionality of these children is vital for preserving a high quality of life (QoL) and reducing all cause mortality.[7] Physical activity (PA) and exercise has been shown to enhance QoL in healthy children, as well as in children with various chronic diseases.[8–10] PA is defined as "any bodily movement produced by skeletal muscles that result in energy expenditure" by Caspersen et al.[11] Exercise is defined as "planned, structured, and repetitive bodily movement done to improve or maintain one or more components of physical fitness".[11]

Physically active children and adolescents have lower blood pressure levels, more favorable lipoprotein levels, higher bone density, and decreased adiposity compared to their sedentary

* Corresponding author.
E-mail address: wriner@mailbox.sc.edu (W.F. Riner)
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counterparts.[12–14] Psychological health of the child has also been shown to be affected by PA.[15–17] Children that are physically active benefit from increased self-esteem, increased feelings of wellbeing, and lower levels of anxiety and stress,[15–17] and PA not only benefits the participant during childhood and adolescence by reducing the immediate risk for conditions such as diabetes, obesity, and cardiovascular diseases, but youth PA participation has been shown to reduce future risk of chronic diseases in adulthood.[18–20]

PA has also been shown to play a role in optimal growth and development.[21] Basic motor skill development in preschool aged children has been significantly associated with moderate to vigorous PA and participation in organized sports.[22,23] Although the association is low, it has been sustained.[23–25]

During the past decade or so, there has been considerable research literature regarding the decrease in PA among children in general. These studies have included epidemiological,[26] longitudinal,[27] methodological,[28] and compliance[29] based investigations. An outcome has been the development of a national standard for children in the U.S. of at least 60 min of moderate to vigorous activity and was formulated by a systematic literature review.[30] Moderate to vigorous PA is defined as activities requiring 5–8 metabolic equivalents (METs).[31] Activities that would meet this requirement would include brisk walking, bicycling, and active outdoor playing.[30] The consequences of too little activity or too much sitting have also been associated with increased risk of several chronic diseases in individuals during childhood or later in life.[32–34] In addition, there is evidence that appropriate PA is beneficial in management of, or recovery from numerous health problems.[35] The mechanism involved is most often that of increasing functional reserve, increasing residual capacity, or improving peripheral function, not that of altering the course of chronic disease.[7] The role of PA and just simply having fun cannot be overestimated.[36,37]

This review outlines the relationship of some prominent childhood chronic diseases and PA. The specific chronic health conditions addressed in this paper are congenital heart disease (CHD), asthma (exercise-induced asthma (EIA), exercise-induced bronchospasm (EIB)), and cerebral palsy (CP). These conditions were chosen due to their prevalence and/or their relationship to exercise or PA.[38,39] Our main concerns are the impact that the condition has on the ability of the child to be physically active, the potential exercise benefit for children affected by the condition, and any role that exercise testing might have in diagnosing or treating the condition.

2. Relationship of chronic health conditions and PA in children

For children without any obvious limitations, PA and exercise are beneficial for the overall health and wellbeing of children as well as for those children with a chronic health condition.[35] However, depending on the particular condition, PA and exercise may need to be modified significantly when chronic health conditions affect physical function. The modifications often needed involve adjustment of the prescribed exercise intensity and volume.[40,41] At the same time, some activities may need to be avoided because of the increased risk of injury specific to the condition. Another factor that must be considered is that some conditions may alter normal growth and development patterns.[42] Therefore, the developmental age may not be on pace with the child's chronological age.

Great care must also be taken to reassure parents, who are apprehensive about PAs they perceive as too risky or strenuous for their child.[43,44] Considerable effort by the medical management team is likely required to assure all involved that as long as the appropriate limitations are considered, PA can be functionally beneficial and lead to an improved QoL.[44–46] When not contraindicated, children with chronic health conditions are encouraged to participate in an active lifestyle throughout the day.[43]

2.1. CHD

CHD is the most common birth defect and the leading cause of infant death.[47] However, some scientists have reported that CHD affects less than 1% of births per year.[48,49] Breakthroughs in cardiovascular disease diagnosis and medical intervention over the last century have led to better survival rates and more newborns with CHD reaching adulthood.[50] Although there are many subtypes of CHD, the most common are ventricular septal defects which can range from tiny muscular defects that close in the first year after birth to large lesions that require surgical intervention.[51]

Most cardiovascular problems in childhood are related to congenital abnormalities of the heart anatomy. This altered anatomy often results in little or no limitation of exercise capacity. The lesions are grouped according to their respective effects on the blood flow and include:

- Left-to-right shunts, resulting from ventricular septal defects (VSD) and atrial/septal defects (ASD) resulting in excessive blood flow to the lungs.[7]
- Right-to-left shunts, resulting from tetralogy of Fallot (TOF), tricuspid valve atresia (TVA) and transposition of the great arteries (TGA), mixing the deoxygenated systemic flow with the pulmonary venous blood causing cyanosis.[52]
- Obstructive lesions, resulting from aortic valve stenosis (AS) and coarctation of the aorta (COA), causing interference with outflow, requiring more work by the left ventricle to generate enough pressure to overcome the resistance.[7]

Single ventricle conditions are the most complex anomalies to deal with.[53] In general, the earlier some of the defects are repaired, the less the chronic condition's effect on the exercise capacity.[53] The key to having a normal functioning physiology is for the repair to result in four functional chambers and great arteries that are able to carry blood via normal routes. If the repairs are successful, the physiology and resulting hemodynamics will more likely fall within normal limits, and the system will function appropriately and pose little, if any, limitation on exercise capacity. Exceptions can occur when residual problems are present. The number of defects that do

result in significant physiological consequences is small and must be repaired surgically.[53] These more complex anomalies that require surgery are:

- Single ventricle − the Fontan procedure establishes direct return of the systemic flow to the pulmonary circulation. The single ventricle is then responsible for the systemic output. This procedure leaves the patient with significantly impaired exercise capacity due to inability to adequately increase cardiac output to meet demand.[54]
- TOF results in significant pulmonary involvement and chronotropic impairment. Following surgery to close the VSD and to reduce the pulmonary stenosis, the aerobic capacity remains mildly to moderately reduced.[53]
- TGA must be corrected to sustain life. The current standard procedure is the arterial switch of the anatomically reversed great arteries, moving the aorta to the left ventricle and the pulmonary artery to the right ventricle where they belong.[55] Though this life-saving procedure offers advantages over the previously used atrial switch technique, this procedure still results in varying degrees of exercise capacity.

Norozi et al.[56] compared the maximal exercise capacities of children with congenital heart defects to those of a normal control group. The children with only the simple CHD (VSD and ASD) achieved work capacities comparable with those of the normal subjects. More complex conditions (TOF, TGA, and single ventricle function) resulted in greater functional limitations.

2.1.1. Benefits and precautions related to PA for children with CHD

The need for supervised rehabilitation programs for children with CHD has been considered in two earlier opinions.[57,58] The major focus is on the efficacy of the rehabilitation program to develop PA tolerance that will allow the child to have normal function following surgical repair of the defect. Most repairs result in the ability to lead a normal active life. Again, some investigations have observed that because of the complex mechanisms involved in these conditions that the child might benefit more from supervised intervention. Rhodes et al.[59] studied the effects of a 12-week cardiac rehabilitation program on the exercise capacities of 16 children with repaired CHD. Eleven of the subjects had Fontan procedures completed, and these 11 children had improved peak exercise performance. The increased peak oxygen uptake (VO_{2max}) and work rate were associated with significantly increased peak oxygen pulse. Rhodes et al.[59] concluded that formal cardiac rehabilitation will improve exercise performance and reduce morbidity in children with complex CHD. In a follow-up study of the same children, Rhodes et al.[60] found that the children who participated in a rehabilitation program retained many of the benefits when reevaluated approximately 7 months after exercise programming was completed.

Significantly altered anatomy involved with the more serious congenital heart defects lead to heart function that may not support optimal accommodation of high levels of exertion.[54] Whereas, less complicated lesions may allow normal, or near normal, response.[44] However, even when the hemodynamic limitations are substantial, such as in Fontan circulation, exercise training has been shown to improve exercise capacity.[53] In either case, daily PA, focused exercise, and participation in some level of competitive athletics is encouraged for most children with congenital problems.[61]

2.1.2. Recommendations for PA and sports participation for children with CHD

Asymptomatic children who have minimal cardiovascular defects and those who have undergone successful surgery should be allowed and encouraged to lead a physically active lifestyle and to participate in athletics.[44,61,62] The more complex anomalies, TOF, pulmonary atresia with VSD will require more complex repair and may result in residual symptoms and less effective hemodynamics even after surgery. The consequence is greater risk and limitation in accommodating physical exertion.[56] Therefore, the 36th Bethesda Recommendations limit sports participation to those activities that require lower exercise intensity.[62] PA or exercise training will improve exercise capacity in children with even the most complicated circulatory concerns.[44] Furthermore, risks associated with affected children not being physically active exist. For example, obesity is associated with the presence of CHD which may contribute to additional cardiovascular problems and other health risks in later life.[63] Holm et al.[64] found an increased risk of impaired motor competence in children with complex CHD.

Specific recommendations for PA and sports participation by children with CHD include:

- Most competitive sports and recreational exercise are considered safe for patients with mild forms CHD.[65,a]
- Intermediate or moderate intensity sports should be considered in patients with moderate forms of CHD.[65,a]
- In severe forms of CHD strenuous exercise could be detrimental to the patient and therefore should be avoided.[65,a]

2.2. Asthma

One of the most common respiratory disorders in childhood is asthma.[67] This condition is characterized by chronic airway inflammation with periods of reversible obstruction and currently affects approximately seven million children in the U.S. under the age of 17 years.[68] Higher prevalence rates are seen in females (9.2%) than males (7.0%) and among African American (11.2%) and American Indian or Alaska native Americans (9.4%).[68]

[a] In all cases it is recommended that a comprehensive history and physical examination be completed by a cardiologist before any sports participation is considered.[65] For recommendations on specific conditions please refer to the 36th Bethesda Conference: Task force 2: Congenital heart disease[62] and Maron et al.[66] article entitled *Recommendations for physical activity and recreational sports participation for young patients with genetic cardiovascular disease*.

Studies have reported significant PA limitation in children with asthma. Storms[69] reviewed the literature concerning EIA, and identified two levels of involvement. The first level is constriction of the bronchi following PA in persons with otherwise normal lung function. This condition is sometimes referred to as EIB. The other condition is EIA which refers to a triggering of an asthma attack caused by some other condition(s) occurring as a result of, or accompanying PA. These conditions include cold air, environmental pollutants, and increased ventilatory volume and the resulting drying of the airway. Swimming has been recognized as being less likely to cause symptoms of asthma than land-based activities due to the warmer, more humid environment. Swimmers who are asthmatic have been more successful than asthmatic land-based athletes.[70]

2.2.1. Benefits and precautions related to PA for children with asthma

One possible benefit of routine PA or exercise is that increased cardiorespiratory fitness may lessen the occurrence of EIB/EIA by reducing the ventilatory requirement of a given work rate.[71] This increased functional capacity would possibly reduce the potential drying effects of airflow into the lungs, and thus reduce the risk of airway spasm. Matsumoto et al.[72] studied the effects of 6 weeks of swim training on asthmatic children and found that exercise training did improve aerobic capacity compared to a control group. However, there are precautions for swimming related to response to facial immersion and to sensitivity to chlorine.[70]

Considerable attention has been given to the relationship of asthma and obesity in children. The question is whether children with asthma are more likely to be obese or if obese children are at greater risk of becoming asthmatic.[73,74] Eijkemans et al.[75] did not find a lower PA level in children with asthma symptoms when compared to non-symptomatic children. However, Black et al.[76] did find a greater risk of asthma with increasing obesity in youth.

2.2.2. Recommendations for PA and sports participation for children with asthma

Children affected by chronic asthma or bronchoconstriction and who are involved in PA, frequently will avoid exertion that requires higher ventilation.[71,73,77] Parents become apprehensive when their children have difficulty breathing.[7] Thus, effective management of the hyper-responsiveness is accomplished either by pharmacological means or as a consequence of improved fitness.[39,78]

A phenomenon characterized by repeated bouts of exercise interrupted by recovery periods has been shown to result in a "refractory period" which lasts 2–4 h.[79] During this refractory period the child can participate in vigorous PA without respiratory problems. If the individual learns to induce this state of refractoriness appropriately through warm-up activities, this technique is an effective tool for managing the breathing difficulty associated with exertion and the related anxiety.[79] Avoiding exercise in cold, dry environments also reduces risk for symptoms.[69,79] For example swimming usually takes place in a controlled temperature environment and is less likely to trigger an attack.[39,72]

Exercise is also an effective diagnostic tool for evaluating the symptomatic child.[80] The exercise challenge test provides information that is more definitive than the traditional static pulmonary tests. In addition to improved diagnostic results, the exercise test also provides information that is helpful in developing PA programs or in prescribing specific exercise protocols that are more individualized and provide additional confidence for the child and parent that exercise is safe.

Specific recommendations for PA and sports participation by children with asthma include:

- Children with asthma may participate if symptoms are well controlled.
- Detailed records of history of symptoms, triggering stimuli, treatments/interventions and description of recovery should be maintained.
- Appropriate challenge testing should be administered to confirm EIB with a drop of 10%–15% in FEV_1 after 6–8 min of submaximal exercise, followed by a positive response to a β-2 agonist.
- An eucapnic voluntary hyperventilation test is recommended for athletes.
- Optimal long-term control of asthma may be achieved by use of leukotriene inhibitors, inhaled corticosteroids and/or long-acting β-2 agonist. Overuse of short-acting β-2 agonist should be avoided.
- Asthmatic children should use inhaled β-2 agonists 15–30 min prior to beginning exercise.
- Scuba diving is not recommended for children who have symptoms of asthma or abnormal pulmonary function tests (PFT).
- National and international athletes who have asthma symptoms will need medical confirmation from a qualified physician of diagnosis and need for certain medications.[39]
- Rice[61] also reported that asthmatics could participate in sports. Only those with severe symptoms would need to alter training or competition. Adequate medical management should be provided. Scuba diving was not recommended for asthmatics.

2.3. CP

CP is the largest single cause of childhood physical disability[81,82] and is defined as a chronic movement disorder or posture of cerebral origin with early onset during childhood[7] and is not a result of a progressive disease.[83] Prevalence varies from 1.5 to more than 4 cases per 1000 live births.[84–87] Incidence rates are higher among boys.[88] Functional limitations can vary greatly within a CP diagnosis. A 2006 population based study found that 56% of children with a diagnosis of CP were able to walk independently while 11% could walk with a handheld mobility aide, and only 33% were capable of limited or no walking.[88] Boulet et al.[89] reported that 41% of children with CP were limited in their ability to crawl, walk, run, or play. Current information indicates that varying degrees

of problems with impaired motor control and poor balance do exist and usually lead to decreased PA levels.[90–92] Reduced PA levels result in further deconditioning and exacerbation of difficulty with movement.[93] These insights are supported by Maher et al.[91] who concluded that children with CP are less active than peers without developmental problems.

2.3.1. Benefits and precautions related to PA for children with CP

Children with CP may have significant PA limitations due to movement and posture abnormalities.[94] Seizure, cognitive, perception, and communication disorders may further complicate medical management.[95] The difficulty with locomotion and poor energy movement economy that result from CP make benefits such as improved cardiorespiratory fitness more difficult to achieve.[35] Spasticity, impairment of motor control, and poor balance also increase the risk of injury associated with some forms of PAs. Therefore, aerobic fitness is typically lower in affected children.[95] Anaerobic capacity[96] and muscle strength[97] deficits are also present with CP. Although children with CP can realize benefits from being physically active, there are also significant exercise limitations and risk.[35] Any gains in physical fitness and function capacity are rapidly lost if exercise training is interrupted or stopped.[98]

2.3.2. Recommendations for PA and sports participation for children with CP

Participation in PA and sports is viewed as beneficial by children with CP. As reported by Verschuren et al.,[99] optimization of QoL and improvement of physical fitness are the primary goals of any PA or exercise training program.[94] Verschuren et al.[99] randomly assigned children with CP to either exercise training or a control group. Significant improvement was reported for aerobic, anaerobic, and neuromuscular function, athletic competence, and QoL measures. The exercise training regimen consisted of eight standardized aerobic and eight standardized anaerobic activities. Verschuren et al.[100] concluded that children with CP benefitted from exercise training that is designed to target lower-extremity muscle strength and cardiovascular fitness. Scholtes et al.[101] found that a 12-week progressive resistance exercise training program increased muscle strength in children with CP, but did not increase walking ability. These findings are supported by previous reports.[102–104]

Though children with CP should be involved in PA and exercise, there are factors that should be considered as the programs are being developed. The activities should be enjoyable and within the child's capabilities as determined by the degree to which CP affects their functional ability.[105] In addition, because CP is a condition involving motor control, balance, and movement, caution is warranted in the selection of PAs or exercises that expose children with significant limitations to risks such as falls or injury from exercise equipment. These considerations become important when selecting testing protocols, or activities and equipment used for exercise testing and in developing PA or exercise programming.

Specific recommendations for PA and sports participation by children with CP include:

- Children with CP should be as physically active as their medical condition allows.
- The activities should focus on increasing aerobic capacity, improving mechanical efficiency, increasing strength and muscle function, and enhanced locomotion.
- Suggested activities include mobility challenging events and games, such as running and other sports, wheelchair and cycle events for those with greater limitations, swimming and other water-based, mat exercises, for more profoundly affected children and resistance exercises.
- Motivation and encouragement are essential. A sustained physically active lifestyle is essential if the individual is to achieve and maintain functional capability.[7]

3. Exercise testing of children with chronic health conditions

Exercise testing of children with chronic health conditions can provide useful information for the clinician, for parents, and for the child. The clinician can use the data obtained for diagnosis, establishing a prognosis and as the basis for decisions regarding recommendations and contraindications for PA. Parents and the affected children can gain reassurance about exercise and participation in sports. Tomassoni[106] identified the following indications for exercise testing:

- Determining cardiovascular and pulmonary response.
- Evaluating symptoms associated with exercise.
- Evaluation for exercise-induced asthma.
- Assessment of aerobic capacity, either by maximal or submaximal protocols.
- Assessment of muscular endurance or strength.
- Documenting the course of a progressive disease.
- Evaluating the effects of therapy and rehabilitation programs.

Exercise testing environment, equipment, and protocols for children should be age appropriate and provide a pleasant experience for the child and parent.[40,43] Tomassoni[106] has discussed the use of different protocols and ergometers for assessment of aerobic capacity in children. Anaerobic capacity can be measured using the Wingate Anaerobic Test.[107] Criteria for choosing equipment and protocols for strength testing are provided by Gaul.[108] Children with chronic health conditions may have tolerances and responses to physical exertion that vary widely within and between individuals. Therefore, the evaluation of each individual is based on their specific conditions and limitations. The risks and benefits of exercise testing of children have been previously discussed.[40] Testing of normal children and those with cardiovascular disease should follow the guidelines of the American Heart Association.[109] Exercise challenge testing protocols used to diagnose lung diseases such as asthma are discussed by Teoh et al.[80] Regardless of the method used, the test should provide information regarding the

function of interest and should be conducted in a manner that provides valid and reliable diagnostic data.[110]

Evaluation of children with CP is influenced by individual ambulation limitations.[7] If the child can walk or run, the protocols used may be the same as those used for non-affected children. However, Unnithan et al.[95] reported gait anomalies that resulted in increased energy cost for walking and running. Thus, if a child has limited mobility, the protocol selection will need modification (e.g., the use of arm ergometry rather than a walking or running test).[111] If the child is dependent on a wheelchair for transport, some modification of that vehicle may be the ergometer of choice for that individual. The information gained from the exercise testing is useful not only in developing a PA and exercise program, but also in measurement and evaluation of outcomes brought about by exercise training and rehabilitation.[95]

4. Barriers to participation in sports and PA for children with chronic health conditions

Children with physical limitations caused by chronic health conditions are usually discouraged, and are often prevented, from participating in sports or other pursuits involving PA.[7] CHD, asthma, and CP will limit PA and exercise participation to varying degrees.[35,65,73] Some of these limits are justified due to medical concerns and contraindication.[39,54,65] However, unnecessary restrictions are often imposed because of misunderstandings or "non-disease rationale".[7] For example, obesity can become a limiting factor to PA when another chronic health condition causes weight gain.[112] The extra weight makes involvement in PA less likely to occur, which can lead to more weight gain. There are also social barriers related to ostracism by peers, the perception that children with disabilities are excessively limited in function or the facilities/environment are not suitable for their participation.[99,113,114] A reduction in self-esteem can also occur when significant physical disabilities are present.[115] Bullying is likely a problem and will discourage children from participation.[99]

These barriers and others are usually perceived by parents as being more prevalent and limiting than they really are.[73,116–118] The child with a chronic medical condition is frequently viewed by parents as "vulnerable" which leads to their hesitancy to allow the affected child to become involved in PAs with healthy children. Parents like to see their children become successful. If a child with health related limitations struggles in any endeavor, the parent often views their involvement negatively.[99] If, however, the parent views involvement as physically and psychologically beneficial to the development of the child, this positive attitude will facilitate participation. Coupled with the usual inclination of children to be physically active and competitive, support from the parents will lead to optimal involvement within the limitations of the child.[99,119] Optimizing the opportunity for children with disabilities to participate in appropriate PA can contribute to social and physical growth and development.[45] Once again, good communication with the child and the parent will facilitate overcoming these barriers.

5. Conclusion

Most children are not affected by health conditions that limit involvement in PA and exercise. Participation in sports and/or an active lifestyle are essential for normal growth and development.[22,23] Even children with chronic health conditions can and should be allowed to participate in PA and exercise with minimal restrictions. Physicians, parents, and other caregivers should not be overprotective with these children. Although serious concerns exist for some, benefits of appropriate PA and exercise programming outweigh the risk of injury in the majority of cases. While consultation with a physician is paramount, Rice[61] points out that for most chronic health conditions the American Academy of Pediatrics recommends participation in most athletic activities for children and adolescents with caution regarding increased risk of injury and exacerbation of the child's medical condition. The health enhancements resulting from PA and exercise training include improved physiological, psychological, and sociological function.

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